



Physics Aspects of a RIA Facility

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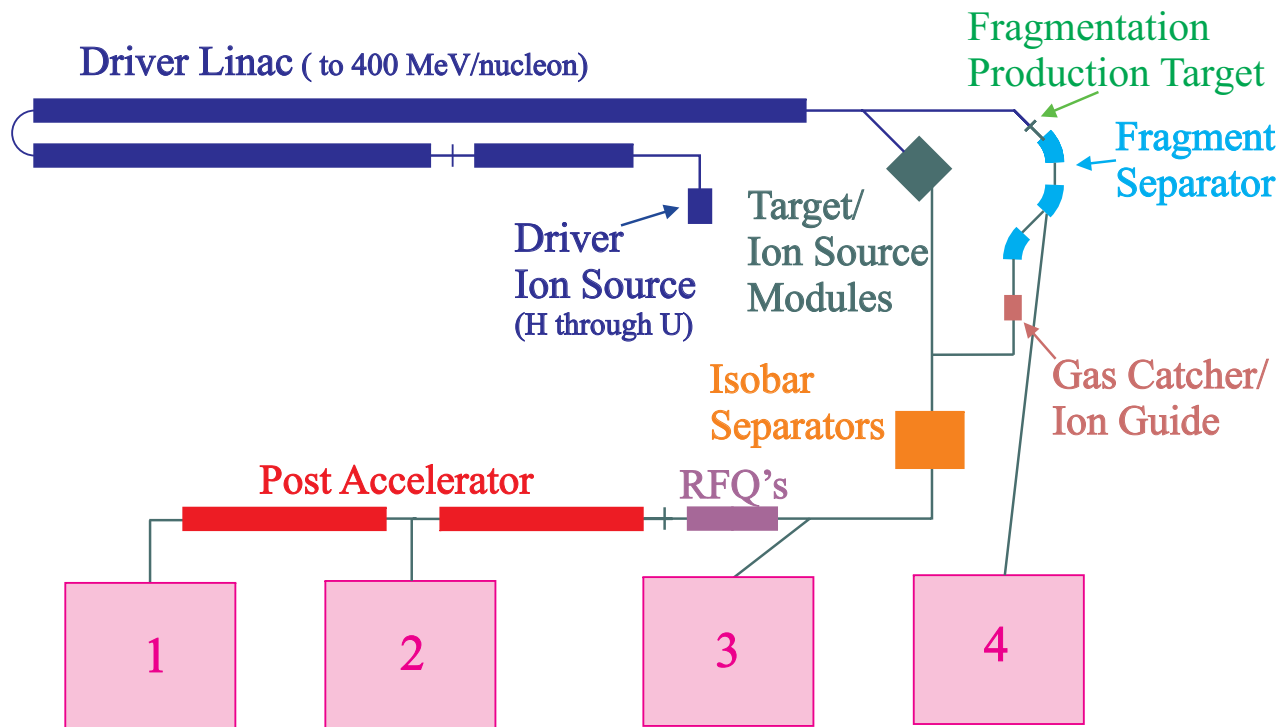
- ➔ **The Nature of Nucleonic Matter**
- ➔ **The Origin of the Elements**
- ➔ **Tests of the Standard Model**

Rare Isotope Accelerator - RIA

- Most intense source of rare isotopes

- High power primary beams up to U at 100kW and $E > 400$ MeV/nucleon.
- Possibility to optimize the production method for a given nuclide.

- Four Experimental Areas (simultaneous users)

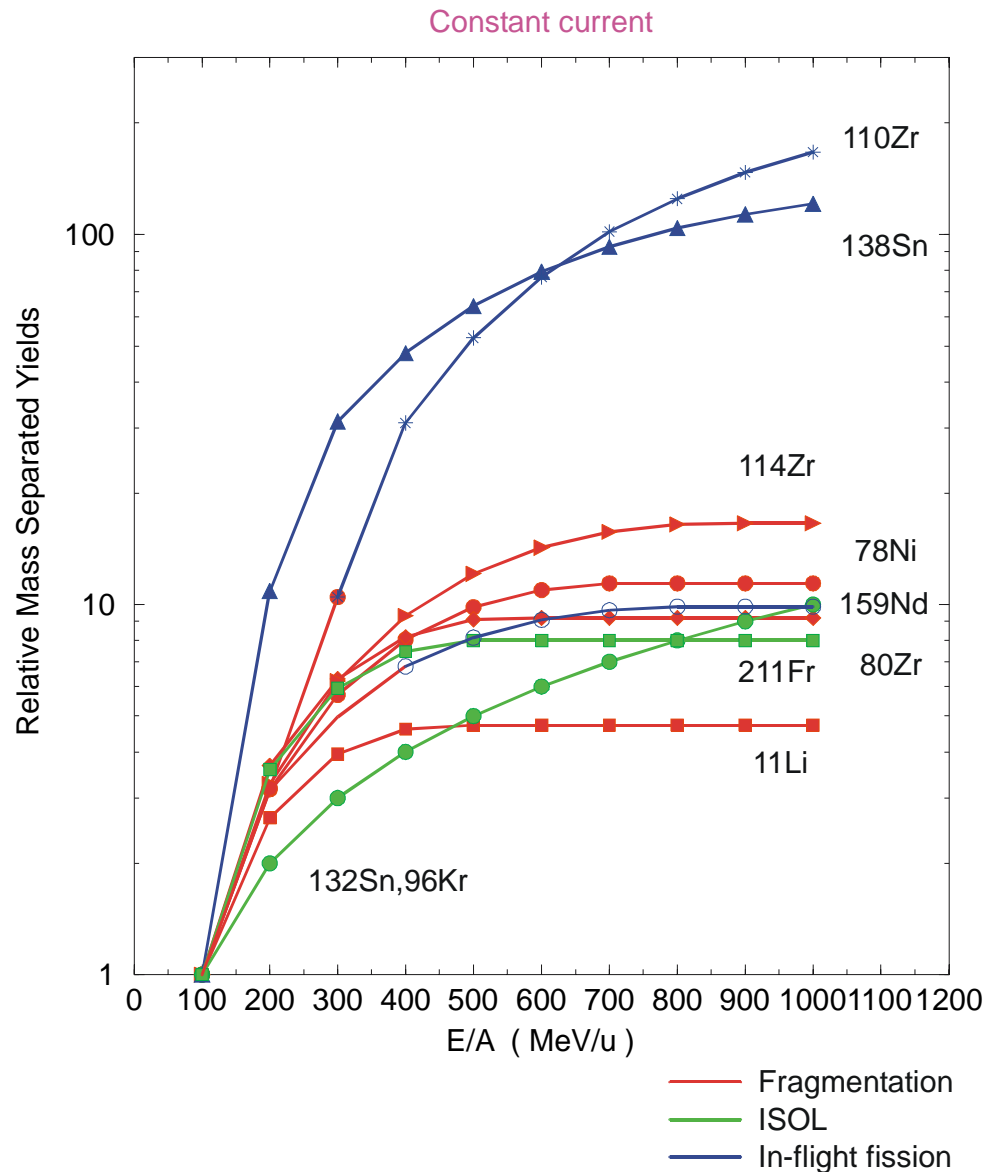


Experimental Areas:

1: < 12 MeV/u 2: < 1.5 MeV/u 3: Nonaccelerated 4: In-flight fragments


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Optimization of the Driver Linac Energy



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What scientific questions will RIA answer?


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- Origin of the elements and energy generation in the cosmos by nuclear processes
 - Supernovae science (requires nuclear science input)
 - The nature of neutron stars (x-ray bursts, crust and bulk properties)
 - Nature of nucleonic matter
 - What combinations of neutrons and protons can make up a nucleus?
 - What is the appropriate, comprehensive model for nuclei and how do we understand it in terms of nucleon-nucleon interactions and ultimately in terms of the strong interaction?
 - Can we understand the nature of unusual forms of nuclear matter (halos, skins)?
 - What is the isospin dependence of the nuclear matter equation of state?

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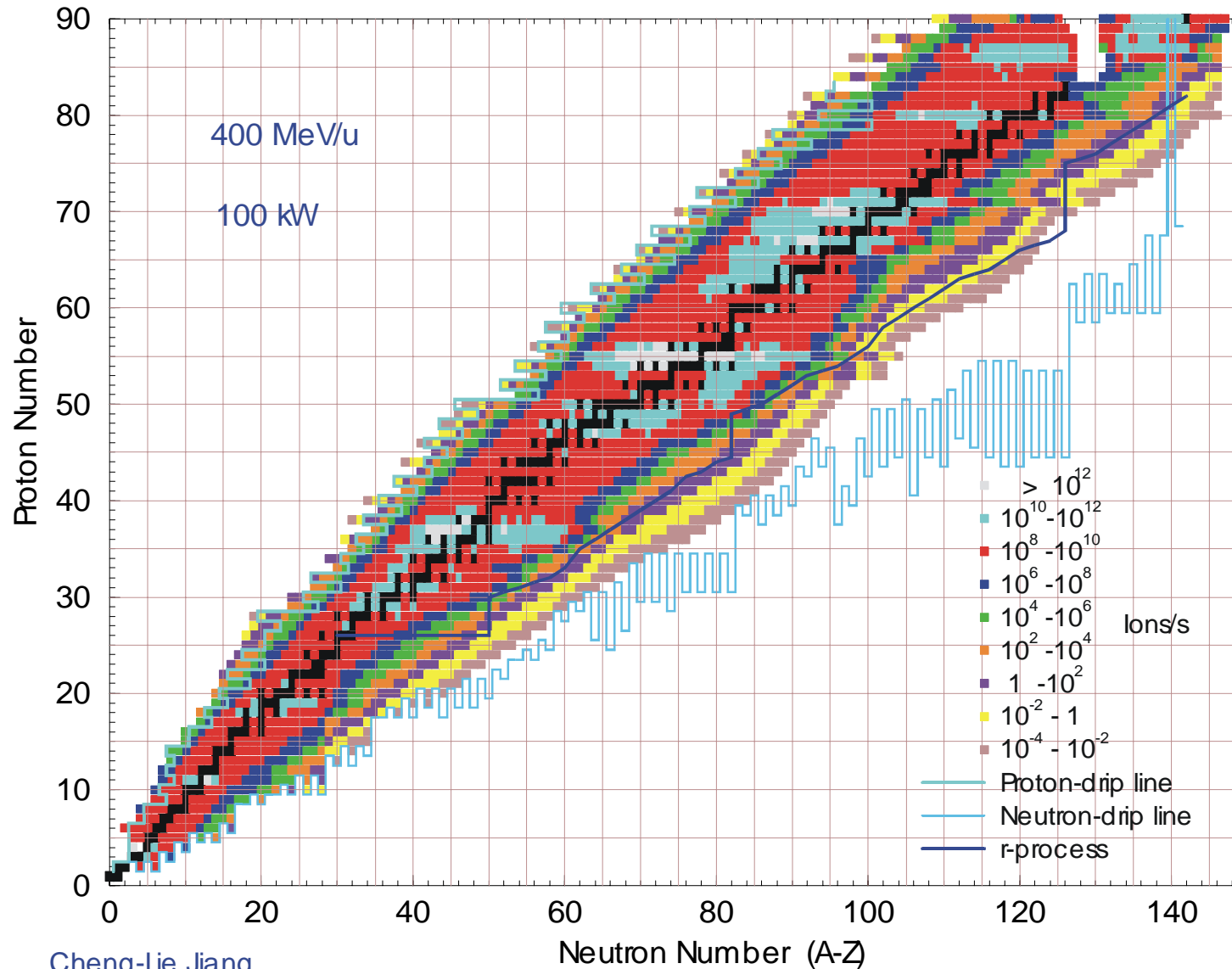
- Tests of the standard model
 - What is the nature of CP violation? The best probe of flavor-conserving CP violation is in the measurement of an atomic EDM. Radon isotopes provide good cases for these studies.
 - RIA will exploit the larger Parity Violation in Francium isotopes to search for physics beyond the Standard Model.
 - Are there weak interactions beyond V-A?
 - RIA may help improve the precision of the measurement of V_{ud} in order to test the unitarity of the CKM Matrix.

What is the significance of RIA for science in general?



Astronomy CHANDRA INTEGRAL HUBBLE	New astronomical observatories and observations	↔	Nuclear properties of nuclides far from stability
Mesoscopic Physics	Small scale quantum systems (femto-technology)	↔	The nature of nucleonic matter and many-body quantum systems
Particle Science	Beyond the Standard Model	↔	Availability of nuclei with special features and/or decay modes

The Discovery Potential of RIA



Optimized
production
of each
Nuclide:

- Fission
- Fragmentation
- Fusion
- Spallation

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Sample Experiments at RIA

- Limits of nuclear stability
 - Nuclide identification (1/week)
 - Fission mass surface (1000/s)
 - Super-heavy Elements ($>10^9$ /s for mid-mass nuclei)
- Nuclear bench marks (Magic Nuclei)
 - ^{132}Sn (10^9 /s)
 - $^{48,78}\text{Ni}$, ^{100}Sn ($>.01$ /s)
- r-process nuclides
 - Half-lives (1/d)
 - Masses (>100 /d)
- Evolution of structure with isospin (neutron skin)
 - Single step Coulomb excitation, Knockout (>0.01 /s)
 - Multi-step Coulomb excitation (>100 /s)
 - Nucleon transfer ($>10^3$ /s)
- Halo Nuclei
 - Wave functions (>0.01 /s)
- Tests of the standard model
 - Rn ($>10^9$)
 - Fr ($>10^9$)

Advantages of ISOL/Reaccelerated Beams



- Stopped and cooled beams for trap measurements (e.g., Rn and Fr)
- High quality beams at or near the Coulomb barrier
- Low energy reactions mechanisms
 - Fusion/Evaporation
 - Near barrier transfer
 - Proton and neutron stripping reactions for the study of single particle and multi-particle states
 - Coulomb excitation (multiple excitations to study higher lying states)
 - Direct measurement of resonant and direct capture reactions
- Experimental considerations
 - Thin targets ($100 \mu\text{g}/\text{cm}^2$)
 - Isobar separation is required
 - Reaccelerated beam experiments can work with 10^3 ions/s or more (ANL,ND,TAM)

Advantages of Fast Beams



- > 50MeV/u without reaccelerating
- High energy reactions mechanisms
 - Eikonal methods for direct reactions
 - Giant Resonance excitation
 - Single-Step Coulomb excitation (E1/M1/E2)
 - EOS studies (flow, balance energy)
 - Charge exchange
- High sensitivity
 - Thick targets (g/cm^2 vs. mg/cm^2) and 1000-10,000 gain in luminosity
 - Relatively easy identification of single ions (A,Z identification)
 - Ability to work with atoms/week (^{48}Ni GANIL, ^{100}Sn GSI/GANIL)
 - Extend the scientific reach to 4-5 mass units farther from stability

Comparison of RIA to other RI Facilities



- NSCL CCF is lower in yield by a factor of 20 for the lightest elements and more than 10,000 for heavier elements.
- ISAC/TRIUMF is limited to traditional ISOL production of ions. This means intense beams of a limited number of nuclides.
- RIKEN RIF will have 400 MeV/nucleon Uranium, but with 10 to 100x less intensity and no post acceleration capability.
- GSI will have 1 GeV/nucleon Uranium but with 10 to 100x less intensity and no post acceleration capability.
- Europe and Japan are discussing an advanced ISOL facility to complement GSI and RIKEN.

Facility Considerations

- Demands on use
 - The user community is expected to be around 500 scientists per year (total world-wide community is 2000)
 - A typical load will be 1 w/(10 user experiment)
 - 5000 h/y operation implies multi-user operation is required
- Program considerations (10-20 weeks)
 - r-process half-life and mass measurements
 - Changes in shell structure (transfer, CX, knock out)
 - Halo nuclei
 - Atomic dipole, Parity violation
- Isotope “mining” for applications

Summary



- The driver should provide beams of elements from hydrogen (helium) to uranium.
- The desired production energy is greater than 400 MeV/nucleon.
- The facility should be able to provide for at least two simultaneous users.
- Experimental areas
 - Non-accelerated beams
 - Beams of up to 1 MeV/nucleon for astrophysics
 - Post accelerated beams of energy up to the Coulomb barrier for all elements up to Uranium and somewhat higher for the lighter elements
 - Availability of fast beams of energy 50-400 MeV/nucleon